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THE EFFECT OF

BATHS, MASSAGE, AND EXERCISE ON THE BLOOD-PRESSURE

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WILFRID EDGECOMBE, M.D. Lond., F.R.C.S. Eng.

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Reprinted from THE LANCET, June 10, 1899

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THE EFFECT OF BATHS, MASSAGE, AND EXERCISE ON THE BLOOD-PRESSURE.

Mode of observation.—The recent appearance of new instruments for the determination of blood-pressure in the human subject has enabled us to make the following series of observations on the effects of baths, massage, and exercise on the arterial and venous blood-pressure. The hæmadynamometer of Oliver and the pulse-pressure manometer of Hill were carefully compared and found to read alike, but as the former instrument proved to be rather easier of manipulation and possesses a much wider scale it was used throughout. Both maximum and mean arterial pressures were recorded and the venous pressure was taken according to the method described by Oliver.[1] For arterial pressure the radial artery was employed, the subjects being in the recumbent posture except where otherwise stated, with the arm extended on a level with the heart. For venous pressure the veins on the dorsum of the hand or wrist were taken in some subjects; in others those of the forearm, with the same precautions to eliminate the effect of gravity. 10 subjects in all were experimented upon, their ages ranging from 20 years to 60 years. They included marked examples of both low and high pressure. Most of the results were confirmed by repeated observation. In the few instances in which this was not done confirmation did not appear to be necessary.

[1] Journal of Physiology, vol. xxiii., 1898, Part 3; Proceedings of the Physiological Society.

General considerations.—At the outset, before proceeding to discuss the results, it is perhaps expedient to refer briefly to the factors which govern the production and maintenance of blood pressure and to point out how far they can be estimated by the instrument used. The chief factors concerned are the output of the heart, the extensibility and elasticity of the arterial walls, and the peripheral resistance. None of these can be directly measured by the instrument. The maximum arterial pressure, as measured by the instrument, being that force which just prevents the passage of blood along the artery, is a force equal to the sum of the true maximum arterial pressure and the forces requisite to produce distortion of the tissues and artery. The latter factors we are unable to measure, though they probably remain constant for each individual during any short series of observations. The mean arterial pressure is taken as the mean pressure recorded by the instrument when the indicator gives its maximum excursion. The difference between the maximum and mean arterial pressures as thus recorded can serve as an indication of the force with which the blood is discharged if we suppose the rate of discharge to remain the same during the time occupied by the observation. When the rate of working of the heart varies during the period of observation the indication is less reliable.

The two variable factors determining changes in the mean arterial pressure during any short series of observations are the output of the heart and the degree of constriction of the peripheral arterioles; consequently a fall in mean arterial pressure may be caused by a dilatation of the peripheral arterioles or by a diminished output of the heart, the latter being due to a slowing of the rate of working or to a diminished output of blood per beat. A rise in mean arterial pressure will be due to the same factors working in the opposite direction, and a variation in mean pressure can also be caused by variations in opposite directions but to unequal extents of the same two factors.

From the measurement of the venous pressure as recorded by the instrument we can to some extent infer the state of the peripheral resistance, for a constriction or dilatation of the arterioles will be accompanied by a fall or rise respectively of venous pressure, provided the other factors remain constant. Hence variations in venous pressure would serve as a measure of the degree of peripheral resistance were the other factors to remain the same.

Baths.

Cold.—The effect of the cold bath of plain water is to raise the arterial pressures, both maximum and mean, and to lower the venous pressure (see Experiment I.). As in this

Experiment I.—*Cold Bath; two Minutes at 13° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	70	190	130	25
After	72	210	150	10
10 minutes after ...	70	185	125	25

instance the rise in arterial pressure is accompanied by a fall in venous pressure we should conclude that this is caused by a peripheral constriction. The other way the result could be produced—viz., by increased output of the heart—does not seem to be indicated by any variation in the pulse-rate. That the conclusion which we draw from this observation is correct is shown by other experiments specially designed to determine the influence of cold applied to the skin. The rise in pressure obtained is of brief duration in normal subjects, for when reaction sets in the arterial pressure falls slightly below its original level, presumably from arteriolar dilatation, and the venous pressure rises to its initial height; relatively, therefore, to the arterial pressure it is slightly higher than before the bath.

If to cold the effect of percussion be added in the form of a strong needle-douche applied simultaneously to the whole surface of the body the arterial pressure becomes raised to a greater extent than with cold alone. Experiment II. gives the details of the results obtained, the subject having a low initial blood-pressure.

In this case there is a considerable rise in arterial pressure with a small fall in venous pressure and a distinct increase in the pulse-rate. These changes are best explained by supposing them to be due to a moderate amount of peripheral

EXPERIMENT II.—*Strong Needle Bath begun at 37° C. and rapidly cooled down to 16° C.; Time, two minutes.*

—	Pulse-rate.	Arterial pressure, mm. Hg. Maximum.	Arterial pressure, mm. Hg. Mean.	Venous pressure, mm. Hg.
Before	64	115	85	15
After	72	150	115	10

constriction accompanied by an increase in the output of the heart. That we are correct in supposing that the latter factor is at work in this instance is borne out by the results of Stewart's[2] experiments upon the output of the heart. He showed that a moderate increase in the pulse-rate usually corresponded to an increase in the output per second, a result which might explain the whole or part of the rise observed in this experiment. That peripheral constriction also plays a part in producing this rise is indicated by the result of the preceding experiment and by the fact that a simultaneous fall in venous pressure occurs.

Heat.—The effect of warm baths of plain water, on the other hand, is to reduce the arterial pressure to an extent roughly proportionate to the increase of temperature (see Experiments III., IV., and V.).

EXPERIMENT III.—*Hot Bath: 10 Minutes; Temperature 43° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg. Maximum.	Arterial pressure, mm. Hg. Mean.	Venous pressure, mm. Hg.
Before	62	185	130	20
After	64	170	117	15

[2] Journal of Physiology, vol. xxii., 1897, Part 3, p. 172.

EXPERIMENT IV.—*Warm Bath; 15 Minutes; Temperature 38° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	60	190	135	17
After	60	180	130	15

EXPERIMENT V.—*Sitz Bath, Running; 10 Minutes at 37° C., Cooled at Finish to 30° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	66	160	125	17
After	64	135	85	12

In each of these three experiments there is a fall in arterial pressure and a fall in venous pressure, the variation in pulse-rate remaining practically constant. If we contrast the percentage fall of arterial pressure with the percentage fall of venous pressure we find that in the first two cases the fall in venous pressure is in greater proportion than the fall in arterial pressure. A diminished output of the heart would tend to lead to a rise in venous pressure; therefore, as we know that heat produces local vascular dilatation these results are best explained as due in the first place to peripheral dilatation of the arterioles, and secondly to increased capacity of the vascular system resulting from that dilatation. It should be stated with regard to Experiment V. that before the bath the subject felt somewhat chilly; hence his arterial pressure was considerably above his normal and the fall that occurred was greater than would otherwise have been the case.

Heat in the form of hot dry air, applied generally, has a similar effect in lowering the maximum and mean arterial

pressures, but it relatively raises the venous pressure. Not infrequently an absolute rise of venous pressure takes place, though in our experiments the relative rise was more commonly observed (Experiment VI).

EXPERIMENT VI.—*Turkish Bath; General Dry Heat.*

—	Pulse-rate.	Arterial pressure, mm. Hg. Maximum.	Arterial pressure, mm. Hg. Mean.	Venous pressure, mm. Hg.
Before	70	200	135	25
After seven min. in hottest room at 99° C. ...	120	155	100	20
In cooling room after shampooing	74	170	115	20
Before	64	170	125	20
After 20 min. in second room at 77° C.	110	140	85	17
In cooling room after shampooing	70	155	110	20

Here the fall in arterial pressure after exposure to high temperature is considerable, while the fall in venous pressure is insignificant. These changes are accompanied by a marked increase in the pulse-rate which is nearly doubled. In the light of Stewart's[3] researches on the output of the heart the diminished output that accompanies a great increase in the frequency of the pulse may share in the production of the lowered arterial pressure, for he finds that "in general when the pulse rate increases considerably the output per heart beat diminishes while the output per second may or may not alter, but is usually diminished too, although not in the same proportion as the output per beat." Arteriolar relaxation also takes place and both factors act in the same direction and combine to lower the arterial

[3] Loc. cit

pressure. During the cooling process the arterial pressure rises somewhat, but the net result is a fall, while the venous pressure in the one case remains the same and in the other is slightly raised. The rate of heart beat has nearly returned to its original frequency.

Experiment VII. shows the effect of general moist heat with subsequent needle bath.

EXPERIMENT VII.—*Russian Bath; General Moist Heat; 15 Minutes at 41° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg. Maximum.	Arterial pressure, mm. Hg. Mean.	Venous pressure, mm. Hg.
Before	64	155	107	20
After bath and after needle douche two minutes, cooled to 21° C.	60	150	102	17
Before	72	175	130	25
After bath and after needle douche, cooled to 30° C.	70	160	115	25

The needle douche administered after the bath was taken by the first of these two subjects at a lower temperature (21° C.) than by the second (30° C.); the resulting fall in arterial pressure is therefore less in the former case than in the latter, for the lowering of pressure by the moist heat is partially, though not entirely, abolished by the raising tendency of the cold and percussion.

Effect of percussion.—Experiments I. and IV. show the effect of cold and warm immersion baths in raising and lowering respectively the arterial pressure. Experiment II. shows the effect of percussion added to that of cold and thereby greatly increasing the rise obtained. To ascertain further the effect of percussion a warm needle bath at 38° C. was given with the object of seeing whether the raising effect of percussion would overshadow the lowering effect of

the temperature. This was found to be the case, the result being a slight rise in arterial pressure (Experiment VIII.). Contrary to what happened in Experiment I., the venous pressure rose, which tends to show that the peripheral resistance was not increased and that therefore the rise in arterial pressure could not be attributed to this cause. Probably, as in the case of the cold needle bath, percussion leads to an increased output of the heart and this, acting with a diminished peripheral resistance due to the heat, would explain the rise observed in venous pressure. 10 minutes after the bath the mean pressure fell to 105 mm. Hg in consequence of the subject having been wrapped in a warm towel.

EXPERIMENT VIII.—*Warm Needle at 38° C.; Three Minutes.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	72	140	115	15
After	72	145	120	20

Heat and cold alternating.—In the alternating needle bath or Scotch douche, where the temperature is made to rapidly oscillate between warm and cold, the net result is a rise in arterial pressure with a slight fall in venous pressure (Experiment IX.).

EXPERIMENT IX.—*Alternating Needle Bath; Six Minutes; Temperature from 37° to 27° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	60	175	130	25
After	66	190	145	22

Spinal douche.—The addition of a spinal douche to the ordinary needle bath did not seem in any way to enhance its effect, a slight rise in all pressures resulting (Experiment X.).

EXPERIMENT X.—*Needle Bath + Spinal Douche; Six Minutes; Temperature 37°, cooled at finish to 24° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	74	165	110	22
After	70	175	117	25

Saline baths.—To ascertain the effect of mineral constituents in the water the saline-sulphur baths of Harrogate were first experimented with (Experiments XI. and XII.). Of these, the "natural" sulphur bath, consisting of the pure undiluted water raised to the required temperature by passing on its way to the bath through a heated coil, contains about 3·6 parts per mille of total solids, consisting of the chlorides and carbonates of sodium, calcium, and magnesium, the chlorides being largely in excess. Of the chlorides, that of sodium greatly preponderates. The sulphur constituent amounts to about 0 03 part per mille of sodium sulphide, with a small volume of sulphuretted hydrogen gas. The so-called "strong" sulphur bath, consisting of the pure sulphur water raised

EXPERIMENT XI.—*Natural Sulphur Bath; 20 Minutes; Temperature 37° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	72	175	125	22
After	68	140	85	20

EXPERIMENT XII.—*Strong Sulphur Bath; 15 Minutes; Temperature 37° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	70	160	120	22
After	70	150	110	15

to the required temperature by admixture with hot plain water, contains about 2·1 parts per mille total solids, the sulphide amounting to 0·01 part per mille. The result is a very marked fall in arterial pressure in the case of the natural sulphur bath, with an absolute fall, though relative rise, in venous pressure; the strong sulphur bath also gives a fall in mean pressure with a fall, both absolute and relative, in venous pressure. Comparing these with the results of hot and warm plain water baths shown in Experiments III. and IV. the fall in arterial pressure is seen to be much greater in the case of the saline baths at the same temperatures. This water, therefore, would seem to have the effect of enhancing the dilating power of warm temperatures on the peripheral arterioles. How far the effect is to be attributed to the salines in the water and how far to the sulphuretted hydrogen gas we are unable to say.

The artificial *Nauheim baths*, both still and aerated, were next examined. The still baths were made by dissolving 3·2 kilos. of sodium chloride and 85 grammes of calcium chloride in 136 litres of water, giving a proportion of 23 parts per mille and 0·6 part per mille of the two salts respectively. The aerated baths were obtained by the use of Sandow's tablets which contain, in addition to the salines above, a quantity of sodium bicarbonate and citric acid for the production of effervescence (Experiments XIII. and XIV.). The baths were given at the temperatures usually adopted in their therapeutic use, being somewhat lower than the plain water and sulphur baths. As in the case of plain water and of saline-sulphur baths a fall in maximum and mean arterial pressure takes place, though the temperature employed is 34° C. as against 37–38° C in the former experiments. The fall is

EXPERIMENT XIII.—*Still Nauheim Bath; 20 Minutes; Temperature 34° C.; 3·2 Kilos NaCl. and 85 Grammes $CaCl_2$ to 136 Litres of Water.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	54	190	115	5
After	60	140	95	10
20 minutes after ...	60	155	110	7

EXPERIMENT XIV.—*Aerated Nauheim Bath; 20 Minutes; at 34° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	88	165	125	12
After	84	140	97	15
30 minutes after ...	84	145	105	20

greater than that which occurs with plain water and with the strong sulphur bath, though less than that obtained with the natural sulphur bath. This latter example, however, is an extreme case and represents a fall beyond that which usually occurs in this bath. On venous pressure the effect is very marked, both cases showing not merely a relative rise but an absolute increase over the original level. In the case of the still Nauheim bath the subject of the example given had a high maximum arterial pressure with low venous pressure, probably due to a tightly contracted peripheral circulation which the first bath opened up to some extent. A series of baths has a cumulative effect, for in the subject in question the maximum pressure after six baths on alternate days became reduced from 190 mm. Hg to 160 mm. Hg before the bath, and the venous pressure was raised from 5 mm.

Hg to 25 mm. Hg. Where the factor of effervescence is added the result is still more marked and endures for some time even after a single immersion (Experiment XIV.).

Saline-sulphur baths having a more potent effect than plain water baths at the same temperature, and Nauheim baths yielding yet more marked results even at lower temperatures, it appears then that if the lowering of arterial pressure and the raising (either relative or absolute) of venous pressure be due mainly to lessened peripheral resistance, as is probably the case, the amount of arteriolar relaxation caused by immersion in warm water becomes progressively greater as the amount of saline material in the water is increased. Up to what point of concentration this augmentation continues we have not yet been able to determine.

Massage.

Lauder Brunton and Tunnicliffe,[4] experimenting on cats and dogs, have demonstrated that massage of a considerable muscular area causes an initial rise in the general blood-pressure which is followed by a considerable fall, amounting in some instances to as much as one-fifth of the original pressure. G. Oliver[5] in a recent series of articles on blood-pressure is "struck by the singularly small and somewhat variable effects produced by massage in the arteries and veins of normal subjects. Local massage," he says, "does not induce any obvious change in the blood-pressure ...... the effect of general massage may be equally negative. I have, however, observed a slight rise in the arterial pressure (mean and maximum) and a doubling of venous pressure; and this observation probably expresses the general drift of the influence of general massage on the circulation in normal subjects." Our observations lead us to the conclusion that general dry massage, in the form known as *pétrissage*, while it may cause an initial rise of blood-pressure of brief duration, produces as the net result a fall in arterial pressure, both mean and maximum, provided the abdomen be not massaged too vigorously. Deep massage and compression of the abdomen causes an immediate rise in blood-pressure by dispersion of blood accumulated in the splanchnic veins into the systemic circulation. The venous pressure we observed to be always relatively, and in some

[4] Journal of Physiology, vol. xvii., 1894.
[5] Edinburgh Medical Journal, November, 1898.

cases actually, raised, the amount of rise appearing to depend to some extent upon the temperature of the room, being greater in a warm atmosphere. We failed to observe with dry massage so marked a rise in venous pressure as is noted by Oliver. Experiment XV. is a typical one selected from several.

EXPERIMENT XV.—*Dry Massage; Heavy Movements; 40 Minutes.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	88	145	95	15
After 40 minutes' vigorous massage to limbs and body (abdomen excluded)..	88	135	85	17
After 7 minutes' deep massage to abdomen	88	160	105	25

Wet massage in the form of the Aix douche in which massage is administered under a warm douche conveyed by a flexible pipe playing between the hands of the masseur causes an increased effect—that of temperature being added to massage. We observed here a greater fall in arterial pressure than was obtained with dry massage and coincidently an actual rise of venous pressure, sometimes considerable. (Experiment XVI.) The subject taking this bath sits

EXPERIMENT XVI.—*Aix Douche; Temperature 38° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	70	180	135	17
After	64	150	115	25

in the erect posture, consequently the abdominal massage is but lightly performed.

On the other hand, wet massage in the form of the Vichy douche in which massage is administered under a warm needle spray, the subject being in the recumbent posture, causes a rise in all pressures, maximum and mean arterial, and venous. (Experiment XVII.) The difference between the effect of this bath and of the preceding is no doubt due to, first, the percussion of the needle spray tending to raise the blood-pressure (Experiments II. and VIII.), and, secondly, to the fact that the subject being in the recumbent posture abdominal massage is more efficiently performed and hence a rise in pressure results. Personal experience of the two baths bears out this difference, a feeling of languor resulting after the Aix douche and of exhilaration after the Vichy douche.

EXPERIMENT XVII.—*Vichy Douche; Temperature 38° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before	64	117	85	15
After	66	125	95	22

To illustrate the cumulative effect of the Aix douche the following example may be given, from which it will be seen that the progressive result is a considerable lowering of arterial pressure and raising of venous pressure. (Experiment XVIII.) The observations were made on a patient suffering from chronic renal disease.

Our observations, therefore, are in agreement with the experimental results obtained by Brunton and Tunnicliffe that massage lowers the general blood-pressure, but they are somewhat at variance with the statement of Oliver that a rise in arterial pressure expresses the general drift of the influence of dry massage on the circulation, unless he refers to the initial transitory rise frequently obtained. He does not state, however, whether massage of the abdomen was carried out in his experiments; presumably it was, as this is the general course adopted, in which case our observations fall

into line with his, for, as has been shown, vigorous abdominal massage will abolish the fall produced by massage of the limbs and rest of the body and cause a rise in arterial pressure; where this is but lightly performed the net result is a fall. The influence of warm temperatures plus massage, as in the Aix douche, is to considerably augment this fall. In all probability the factor primarily and chiefly disturbed by massage is the peripheral resistance rather than the output of the heart and the result is to be attributed mainly to diminished resistance from arteriolar dilatation.

Experiment XVIII.—*Series of Aix Douches; Temperature 37–38° C.*

—	Pulse-rate.	Arterial pressure, mm. Hg.		Venous pressure, mm. Hg.
		Maximum.	Mean.	
Before (sitting) ...	100	240	155	15
After four baths (sitting)	96	215	130	25
After 12 baths (sitting)	86	180	110	30

Exercise.

The effect of exercise on the blood-pressure has been examined by many observers with somewhat conflicting results. Marey [6] as the result of his experiments found the blood-pressure to be raised during severe muscular exercise, but to be lowered after cessation of exertion. Oertel [7] and others found a considerable rise in blood-pressure following muscular exercise. Lauder Brunton and Tunnicliffe,[8] observing the effects of resistance exercises on the circulation, using the sphygmomanometer of Mosso, found an initial rise in arterial pressure to take place soon after commencement of the exercises. During their continuance the blood-

[6] La Circulation du Sang. Paris, 1881.

[7] Handbuch der Allgemeinen Therapie der Kreislaufs-Störungen. Leipsic, 1891.

[8] Brit. Med. Jour., vol. ii., 1897.

pressure fell to its original level and continued falling after cessation of movement, the fall lasting about half an hour afterwards, when it gradually rose to its initial height. They discuss the probable cause of the discrepancy between their results and those of previous observers and refer it to the different amount of exercise taken. In the case of the earlier observers the exercise taken was more severe and sufficient to increase the frequency of pulse and respiration, while in their own experiments with resisted movements the exercise was of a much gentler nature, insufficient to accelerate either pulse or respiration. They consider the fall in pressure following the exercises to be due in great part to the dilatation which occurs in the peripheral muscular area. The initial rise in pressure they refer in part to reflex cardiac stimulation and in part to the diminution in calibre of the peripheral muscular arteries which occurs during the shortening of the muscles which are called into play. The latter factor they consider the most potent. To account for the fall in pressure that occurs while the muscles are still contracting they suggest the possibility of a vaso-dilating substance being produced by the contraction of muscle. Leonard Hill[9] recently has shown that such moderate exercise as rising from the sitting posture, walking a few steps, and again sitting down is sufficient to slightly raise the mean arterial pressure, the pulse-rate being also raised, while severe exercise in the form of a rapid run causes a considerable rise in pressure, the frequency of pulse and respiration being, of course, increased. The rise thus obtained is of brief duration, the pressure falling to normal within half an hour after exercise and before the pulse-rate has fallen to its initial frequency; subsequently, however, the pressure falls below its original level. Oliver[10] agrees with the general conclusion that exercise raises the mean arterial pressure, but he finds that this result is by no means invariable, the mean pressure, according to him, remaining stationary or even falling in some subjects after exercise. He considers the invariable result of exercise, moderate or severe, to be a rise in maximum pressure, which, he says, is due to increased energy of contraction of the ventricle. Whether the mean pressure becomes lowered or raised depends, he maintains, on the relation between the amount of arteriolar relaxation

9 The Lancet, Jan. 29th, 1898.
10 Edinburgh Medical Journal, October, 1898.

at the one end and the force of the ventricular pump at the other; the former being excessive without undue increase in the latter a fall in mean pressure results, and *vice versâ* a rise. He further states that it is in subjects with a high mean pressure and relatively low venous pressure—that is, in subjects in whom peripheral resistance is high—that a fall in mean pressure is likely to follow exercise, and that when it does a marked rise in venous pressure occurs.

In the endeavour to throw further light on the subject we examined the effects of exercise of various grades of severity from gentle resisted movements upwards through dumb-bell exercises requiring a gradually increasing amount of exertion to the strenuous labour of cycling rapidly uphill, with results which are tabulated below. After corroborating the observation of Hill that the mere rising from the sitting posture and walking a few steps raises slightly the mean pressure we found that if the blood-pressure be taken in any position with the muscular system relaxed, the rendering of the skeletal muscles throughout the body tightly rigid without holding the breath has the effect of at once raising the pressures—maximum, mean, and venous—to a considerable extent, the pulse frequency being also raised. (See Exercise I.). A transient fall in venous pressure may sometimes be noted immediately the muscles contract, probably from constriction of peripheral muscular arteries by contracting muscle fibre; the fall, however, rapidly gives way to a rise. These changes may be explained as partly the result of increased output of the heart, as indicated by the moderate increase in the rate of beat, and partly the result of diminished capacity of the vessels; and the influence of an increased amount of carbonic acid in the blood must not be overlooked.

With resistance movements performed gently without causing a rise in the pulse-rate we obtained results corroborative of those of Brunton and Tunnicliffe—viz., an initial rise (or delayed fall, as in the example given) in mean and maximum arterial pressure, followed by a fall during continuance of movement, with a further fall subsequently and a gradual rise to normal, the venous pressure rising as the arterial pressure falls (Exercise II.). Where, however, the resistance was made stronger and the exercise became such as to increase the frequency of pulse and respiration a rise in maximum pressure resulted, with a fall in mean pressure and a trebling of venous pressure (Exercise III.). If the difference between

the mean and maximum pressures, compared with the mean pressure as taken by the instrument, be any guide to the amount of force with which the blood is discharged it would appear that this must be here increased, and inasmuch as the mean arterial pressure is lowered the amount of peripheral dilatation must be such as to more than counterbalance the effect of increased output, which would tend to raise the mean pressure if other factors remained constant.

Dumb-bell exercises were next taken, those advocated by Sandow[11] being chosen as putting into action successively the main groups of muscles in the body. When slowly and deliberately performed, to avoid quickening either pulse or respiration, an initial rise in all pressures occurred with a subsequent fall during the exercise in arterial pressures and a further rise in venous pressure, the return to normal being complete in 20 minutes after cessation of exercise. (Exercise IV.). This result is practically identical with that given by gentle resisted movements. The same exercises performed more rapidly and vigorously gave as the net result a lowering of mean pressure with slight rise in maximum pressure and a doubling of venous pressure, the exercise apparently increasing the output of the heart without disturbing the rate of working (Exercise V.). When performed more rapidly still and with great vigour in order to quicken the pulse the initial rise in arterial pressure became more marked, increased as the exercise continued, and was sustained to the end, the venous pressure showing a marked rise. Afterwards, however, the mean pressure fell to below normal, while the maximum and venous pressures also fell slightly but still remained well above normal. The effect was of brief duration, for 25 minutes after discontinuing exercise the arterial pressures regained their original level, the venous pressure remaining slightly raised (Exercise VI.). The violent exertion of cycling rapidly uphill against a strong wind caused a rise in maximum pressure with a rise to a less extent in the mean pressure and a large rise in venous pressure, respiration and pulse-rate being greatly accelerated. The arterial pressures fell after exercise to below normal, while the venous pressure rose higher, as occurred in the preceding case, of which this is merely an exaggeration. The length of time that elapsed before the starting-point of pressure was regained was greater after the more severe exercise (Exercise

[11] Strength and How to Obtain it, by E. Sandow. London, 1897

VII.). In these two instances the marked rise in venous pressure would seem to indicate a considerable degree of peripheral dilatation. In endeavouring to account for the rise in arterial pressure the effect of increased CO_2 must

I.—Rigidity.

—	Pulse-rate.	Arterial pressure, mm. Hg. Maximum.	Arterial pressure, mm. Hg. Mean.	Venous pressure, mm. Hg.
Before (sitting)	72	185	135	25
Muscles rigid (sitting)	86	200	150	35

II.—Resistance Exercises (gentle).

Before (sitting)	74	175	130	10
After five minutes' exercise (sitting)...	74	175	130	10
After 20 minutes' exercise (sitting)...	68	165	120	20
10 minutes afterwards (sitting)..	68	160	115	20
25 minutes afterwards (sitting)..	68	175	130	10

III.—Resistance Exercises (more severe).

Before (sitting)	84	165	125	7
After 15 minutes' strong resistance exercises, respirations increased (sitting)	94	175	110	22
15 minutes after (sitting)	84	165	105	17
35 minutes after (sitting)	84	165	120	10

IV.—Sandow's Exercises (5 lb. dumb-bells, very slowly performed).

Before (sitting)	75	187	150	20
After seven minutes' exercise (sitting)...	75	195	155	25
After 15 minutes' exercise (sitting)...	74	175	135	30
20 minutes after (sitting)	75	185	150	20

V.—Sandow's Exercises (5 lb. dumb-bells, moderately severe).

—	Pulse-rate.	Arterial pressure, mm. Hg. Maximum.	Arterial pressure, mm. Hg. Mean.	Venous pressure, mm. Hg.
Before (recumbent)	66	155	125	7
After 25 minutes' exercises (recumbent)	66	160	110	15
VI.—Sandow's Exercises (5lb. dumb-bells, severe, and rapidly performed).				
Before (sitting)	66	160	120	15
After two-arm and two-leg exercises rapidly done (sitting)	84	175	130	27
After exercises 3–6* (sitting) ...	84	170	125	33
After exercises 7–12* (sitting) ...	94	185	135	37
After whole series, 20 minutes (sitting)...	96	180	125	35
Five minutes after (sitting) ...	81	170	110	30
15 minutes after (sitting)	72	165	115	27
25 minutes after (sitting)	68	160	120	20
VII.—Hard Cycling (one mile uphill against strong wind; cold day).				
Before (standing)	78	175	140	15
After (standing)	160	205	160	35
10 minutes after (standing)... ...	120	165	135	40
20 minutes after (standing) ...	100	167	135	45
35 minutes after (standing)... ...	96	173	130	37
50 minutes after (standing)... ...	90	175	140	25
65 minutes after (standing)... ...	90	175	140	17

* These numbers refer to exercises as numbered in Sandow's book.

again be considered. Possibly the rise may be attributed partly to this cause and partly to increased output of the heart, notwithstanding Stewart's statement that where the

pulse-rate is greatly increased the output per heart beat is diminished and the output per second may or may not alter but is usually also diminished.

It would appear, then, that these observations support the conclusions of Brunton and Tunnicliffe that the effect of exercise on the blood-pressure will depend on the nature and severity of the work performed. The first effect of all forms is to raise the arterial pressures to an extent roughly proportionate to the amount of exertion, probably because increased output of the heart tending to raise the pressure is in excess of peripheral dilatation tending to lower it, the arterioles being as yet unrelaxed. If continued exercise be such as to markedly increase the frequency of the heart beat a rise in pressure results which is maintained throughout the exercise if that be severe, the factors tending to raise the pressure (whether increased output, diminished oxidation, or others) more than compensating for the widening of the periphery. On the other hand, if the exercise be less severe and the pulse-rate be not disturbed, arteriolar relaxation takes place while the output apparently may remain the same or at least be not greatly increased, so that a fall in pressure occurs. In all cases the venous pressure rises, the extent of rise being in some degree a measure of peripheral dilatation. After exercise of all kinds the arterial pressure falls below its original height, the venous pressure remaining raised, and the starting point of both is regained in from 20 minutes to an hour afterwards.

The result obtained may vary to some extent with the condition of the subject experimented upon as to being accustomed or not to exercise, inasmuch as moderate exercise may be to him relatively severe. Temperature also appears to be a factor of moment in determining the result, for the fall in pressure after moderate exercise is greater on a warm day and the subsequent return to normal occupies a longer period than in cold weather.

Summary.—1. Cold baths raise the arterial pressures, maximum and mean, and lower the venous pressure; after reaction the arterial pressure falls and the venous pressure rises. 2. Percussion added to cold increases the rise in arterial pressure. 3. Warm baths of plain water lower the arterial pressures and both absolutely and relatively lower the venous pressure. 4. Turkish baths lower the arterial and venous pressures to a greater extent though the fall in venous pressure is proportionately not so great as that in arterial

pressure. 5. Saline baths at warm temperatures lower the arterial pressures to a greater extent than plain water baths at the same temperatures; the venous pressure, though absolutely lowered, is relatively raised; where the amount of saline material in solution is considerable a further lowering of arterial pressure takes place while the venous pressure becomes absolutely raised. 6. Dry massage lowers the arterial pressures and relatively or absolutely raises the venous pressure, provided the abdomen be not massaged too vigorously; when this is done a rise in all pressures occurs. 7. Warm temperature *plus* massage, as in the Aix douche, has a more powerful effect in the same direction than dry massage alone. The effect of a series of Aix douches is cumulative. 8. The effect of exercise on the blood-pressure depends upon the severity of exertion. In all forms an initial rise in arterial pressure occurs; if the exercise be mild a fall occurs during its continuance; if severe the rise is maintained; after exercise, moderate or severe, a fall takes place. The venous pressure is raised during all forms of exercise and remains raised during the subsequent arterial fall. The return to normal after exercise takes place more or less rapidly according to the gentleness or severity of the exercise and the temperature of the atmosphere.

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